III. ENVIRONMENTAL EFFECTS

A. EFFECTS OF NORMAL OPERATION

The effects of normal SRP operations on the environment are described in this section, as follows:

- The releases of radioactivity for 1975 are given, together with a description of trends in quantities released for the 24-yr history of operations and the reasons for increases and decreases in the releases.
- The results of the 1975 environmental monitoring programs are summarized.
- Calculated population doses resulting from radioactive releases to the atmosphere and to the Savannah River are tabulated and compared to other sources of radiation dose such as natural background radiation and medical X-rays.
- Maximum potential health effects to the surrounding population are estimated using conversion factors published by the EPA.
- The population doses and quantities and concentrations of radioactivity released are compared to Federal standards and SRP guides.
- Occupational doses to SRP employees are listed.
- Nonradioactive and thermal effects are compared to state regulations and standards.
- Combined effects with other nuclear plants in the vicinity are estimated.
- Combined effects with non-nuclear plants in the vicinity are discussed.

Potential effects of abnormal operation of the waste storage facilities are described in Part B of Section III.

1. RELEASES OF RADIOACTIVITY

The releases of radionuclides from SRP operations in 1975 are given in Table III-1: Part A, to the atmosphere; Part B, to plant streams leading to the Savannah River; and Part C, to seepage basins and other unlined earthern basins. These releases are compared to applicable standards and guidelines in Part III.A.5.

Previous annual and cumulative releases are tabulated in Appendix A. The effluent monitoring locations from which these releases were determined are tabulated in Appendix E.

The releases to the ground from buried solid waste storage are given and discussed on pages III-19 to 20.

ATMOSPHERIC RELEASES

Atmospheric releases in 1975 included 488,000 curies (Ci) of tritium, two-thirds of which resulted from tritium processing in the 200-H separations area. Essentially all of the remaining releases were associated with heavy water losses from the three reactor areas (100-P, K, and C) and the D_2O recovery plant in 400-D area. Atmospheric tritium releases have varied over the years (Figure III-1) depending on production activities in the tritium facilities and the buildup of tritium in the reactor D_2O coolant. In the separations areas, losses from tritium production in the years 1957 to 1964 averaged about 1,000,000 Ci/yr; for 1965 to 1975, the annual average was about 370,000 Ci. In the reactor areas, the tritium releases increased to a maximum of about 100,000 Ci/yr per reactor in 1964 to 1965. An extensive program to minimize heavy water losses has reduced this release in recent years to 70,000 to 80,000 Ci/yr per reactor, in spite of increasing tritium concentration in the D_2O coolant. In 1975, the releases were 53,000 Ci per reactor.

Mechanisms for noble gas release are discussed in Section II.A.3. Emissions of ^{41}Ar have depended primarily on the differing neutron fluxes in the air space around the individual reactors. The krypton-xenon isotope releases from the reactors have varied with the extent of fuel defects, which are primarily associated with enriched uranium irradiations. The 1975 release of 4000 Ci of krypton-xenon compares to a maximum release of about 160,000 Ci in 1967.

In the early years of SRP operation, fuel cooling times after irradiation were short, and ^{131}I was released in substantial quantities during chemical processing. These releases have been reduced by requiring longer fuel cooling times; 1975 releases from separations processes were 0.1 Ci compared to the maximum (in 1956) of 1580 Ci. From 1968 to 1971, ^{131}I emissions averaged about 30 Ci/yr, primarily from 200-H Area processing of irradiated neptunium; cooling times were further increased in 1972 to minimize iodine releases.

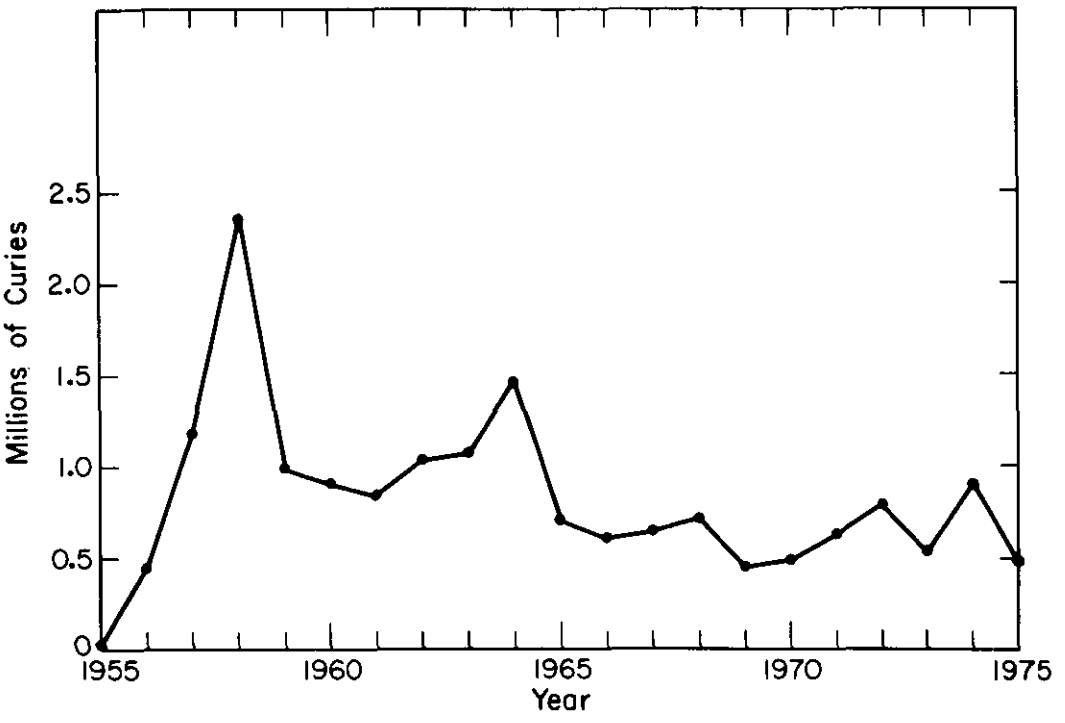

FIGURE III-1. Releases of Tritium to the Atmosphere at SRP

(Includes 479,000 Ci of elemental tritium gas released on May 2, 1974, and 182,000 Ci released on December 31, 1975, during abnormal operations. These releases are treated separately for purpose of dose commitment calculation.)

Particulate emissions in the early years of SRP operation were the result of process variations or malfunctions of filtration equipment, or they occurred before the efficient filter materials were installed. The release of 2.66 Ci of ^{239}Pu in 1955 (see Table A-7) was the result of faulty filtration equipment during startup of the fuel reprocessing plants. The release of 0.0025 Ci of plutonium in 1975 compared to an average release of 0.475 Ci during the period 1955 through 1960.

RELEASES TO PLANT STREAMS

Most of the radioactivity released directly to plant streams leading to the Savannah River comes from the reactor area fuel and target storage basins. Most of the separations areas low-level liquid wastes are discharged to seepage basins and not released directly to the streams. Migration of tritium and strontium from the basins to the streams is a larger source of activity than direct releases from the separations areas (Table III-1).

Tritium releases to plant streams from all SRP sources are shown in Figure III-2. The increased releases of tritium to plant streams in 1972 through 1975 resulted from the need to purge the fuel and target storage basin water in order to reduce airborne tritium exposures in working areas. The tritium concentrations had built up during 1970 to 1972 when the basins were first operated as completely closed systems. The tritium releases result primarily from leakage of the D_2O coolant to the secondary cooling water in the heat exchangers and from purges of the fuel and target storage basins. As previously described in Section II, the amount of tritium in the basins depends on the quantity of D_2O carried with the discharged fuel, targets, and other components. Figure III-3 shows the annual releases from the reactor areas to plant streams excluding tritium, and Figure III-4 shows ^{137}Cs and ^{90}Sr releases since 1960, when analytical techniques for these isotopes were first utilized routinely for effluent analyses. Before 1960, the releases were measured as curies of nonvolatile beta activity. Qualitative analyses, particularly of half-life, of the pre-1960 releases indicated that most of the activity was short-lived and consisted of fission products and 2.3-day ^{239}Np from the discharge of natural uranium fuel with cladding defects (failed fuel elements). The largest annual release before the start of specific analyses was 1300 Ci in 1959, of which it was estimated that 75% was ^{239}Np.

Some other examples of short-term high releases were: 500 Ci of ^{35}S in 1962, caused by the use of cation resin beds in the purification systems; 14 Ci of ^{32}P in 1965 and 10 Ci in 1966 caused by phosphates in K-Reactor D_2O coolant; 87 Ci of ^{131}I in

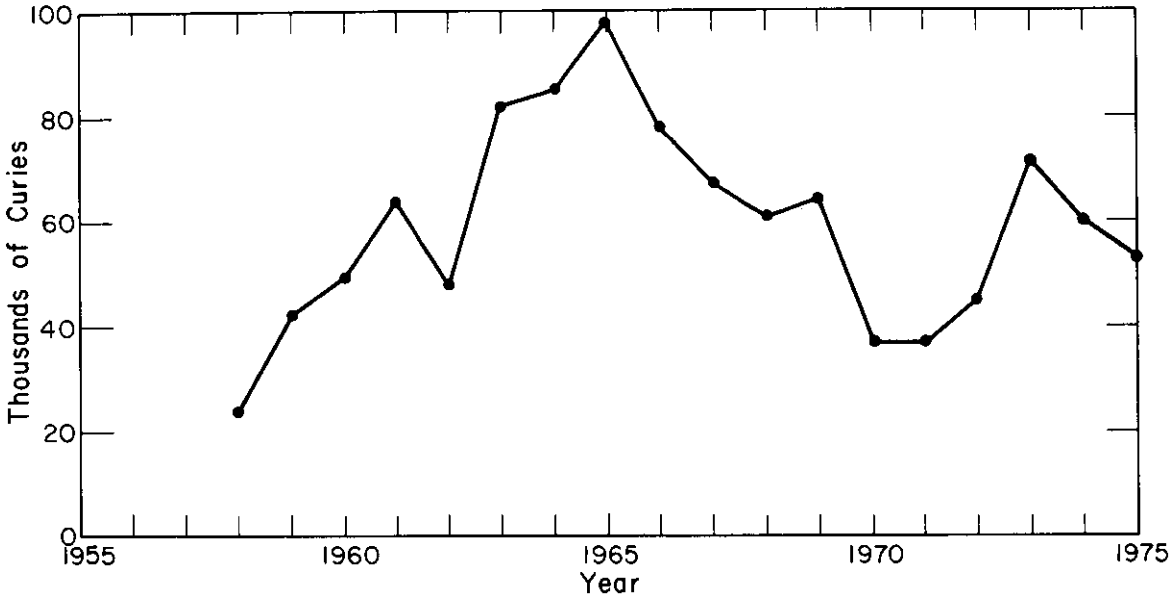

FIGURE III-2. Releases of Tritium to Plant Streams at SRP

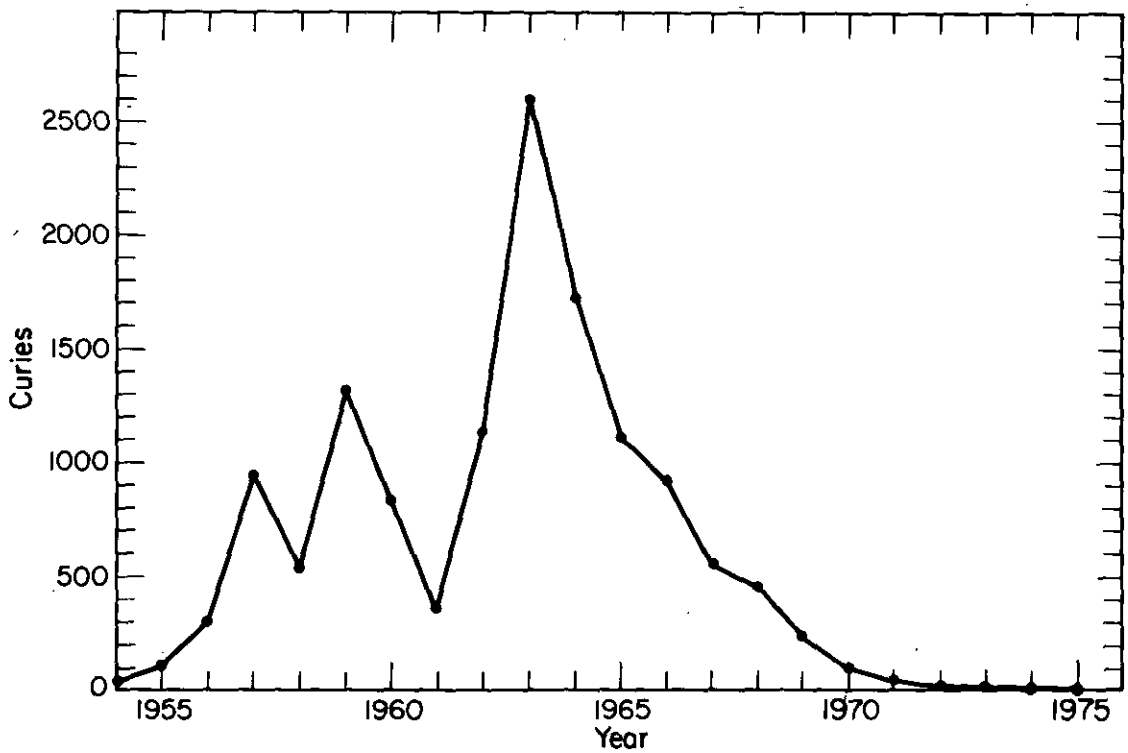

FIGURE III-3. Total Fission Products and Activation Products (not including tritium) Released to Plant Streams from Reactor Areas at SRP

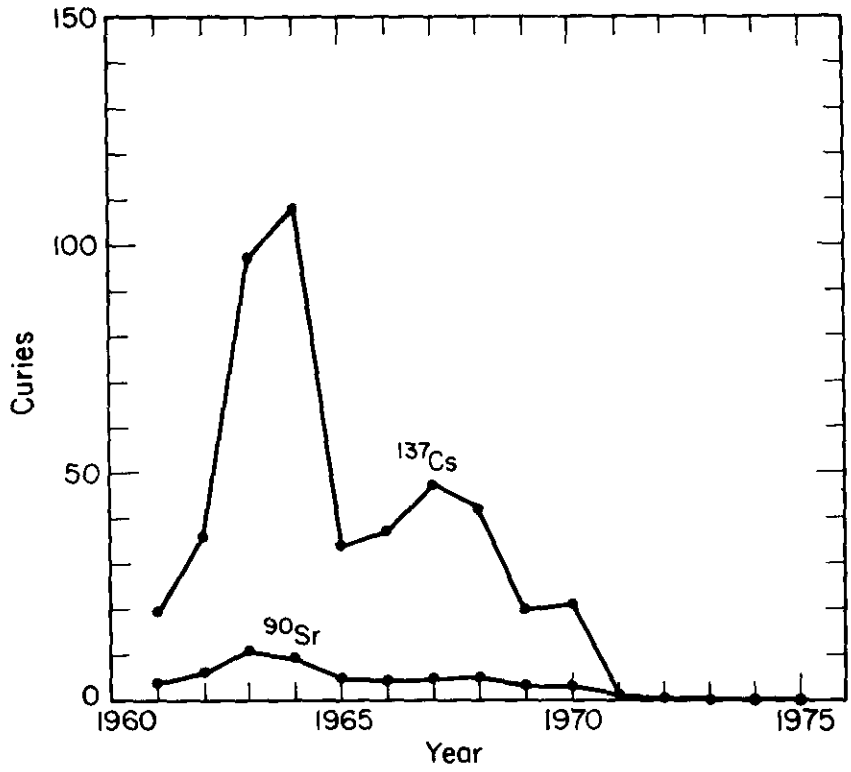

FIGURE III-4. ^{137}Cs and ^{90}Sr Released to Plant Streams from Reactor Areas at SRP

1962 of which 73 Ci were from the discharge of a failed fuel element in P Area; and in 1963, 780 Ci of ^{239}Np and 35 Ci of ^{131}I from R Area, again primarily resulting from the discharge of a failed natural uranium fuel element.

Some of the more prolonged releases were: 1) ^{51}Cr which resulted in part from an apparent change in chromium chemistry of the D_2O coolant associated with the initiation of pD (deuterium ion concentration) control and from wear of stainless steel core rods in the heat exchangers. The releases increased from 60 Ci in 1961 to 200 Ci in 1962, reached a maximum of 1300 Ci in 1963, and subsequently decreased to 240 Ci in 1967 and less in later years; 2) ^{137}Cs releases, from failed fuel elements stored in vented containers, starting in 1963 in R Area with 83 Ci (of 100 Ci for all areas) and continuing in 1964 (93 Ci of 110 total) in R and P areas (the material was transferred to P Area after the R-Area shutdown). P-Area ^{137}Cs releases from 1965 to 1968 totaled 150 Ci of the 160 Ci total for all reactors. Starting in 1968, the ^{137}Cs releases were decreased by transfer of the activity source to the Receiving Basin for Offsite Fuels (244-H). In 1975, only 0.4 Ci of ^{137}Cs were released from the reactor areas.

^{90}Sr releases increased, as did other fission product activities, with the beginning of enriched fuel discharges in 1960. The maximum releases were 10 Ci in 1963 and again in 1964. Starting in 1963, the continuous nature of enriched fuel activity releases, as opposed to occasional discharges of failed natural uranium fuel elements, resulted in the utilization of portable deionizer units for activity removal from the fuel and target storage basins. Use of these units helped minimize aqueous fission product and ^{35}S releases during the 1964 through 1968 period of high basin activities from enriched uranium fuel discharges. The procurement of additional deionizers and improvements in fuel fabrication and disassembly basin operation have resulted in further reduction of basin releases, as can be seen in the 1971 to 1975 values (Figure III-4).

Certain radionuclides released to the effluent streams migrate very slowly to the Savannah River because of deposition in the stream beds and swamps. Two examples of this are natural uranium released from the 300-M fuel fabrication area and ^{137}Cs released to Steel Creek from the 100-P reactor area.

Cumulative and recent releases of uranium to Tims Branch are given in Table III-2. Because much of the uranium released is in the form of suspended solids, considerable deposition occurs in the stream. For example, a 1967 survey of core samples from Steeds Pond (Figure II-2) led to an estimate that 3 to 4 Ci of the 10 Ci of uranium released from the 300 Area during 1954 to 1966 were present in the pond bed.

TABLE III-2

Uranium Releases to Tims Branch from 300-M

Total release, 1955 through 1975	85,000 lb U (24 Ci α)
Maximum annual release (occurred in 1967)	21,000 lb natural U (6.4 Ci α)
Annual release in 1975	∿2,000 lb depleted U (0.4 Ci α)

From 1961 through 1975, about 270 Ci of ^{137}Cs were discharged from 100-P and 100-L reactor areas to Steel Creek. About 170 Ci have been observed in transit at the Road A (SC Highway 125) crossing of the creek, leaving about 100 Ci deposited in the stream bed above this point. Further deposition occurs in the swamp; although no values are available for the amount of ^{137}Cs leaving the Steel Creek mouth, an overall balance since SRP operation began shows about 500 Ci of ^{137}Cs discharged to plant streams, about 300 Ci passing the Road A crossings, and about 100 Ci in transit in the river downstream of all plant discharges (see Appendix A for annual values). Of the approximately 200 curies of ^{137}Cs that has been deposited in the streambeds and swamp below the Road A crossings, aerial and ground surveys of radioactivity estimate that about 24 Ci is deposited in that portion of the swamp that is downstream of the plant boundary (Figure II-2).[1]

RELEASES TO SEEPAGE BASINS AND OTHER UNLINED EARTHEN BASINS

Seepage basins are used at SRP to provide, by means of a soil column, a delay in the time required for radionuclides in waste water to reach plant streams. These radionuclides would be within concentration guides specified by ERDAM-0524[2] before reaching the public zone (the Savannah River) even if discharged directly to plant streams. Shorter-lived nuclides (e.g., ^{51}Cr, ^{131}I, ^{95}Zr-Nb) are retained in soil for sufficient periods to decay to stable isotopes. Nuclides of plutonium and cesium are tightly bound in the soil column and do not migrate beyond the immediate vicinity of the basins. Strontium isotopes are not as tightly bound as cesium but move more slowly than ground water. Tritium moves at the same rate as ground water, but the travel times to streams (several years) and dilution reduce tritium concentrations significantly from those associated with batch discharges.

Tritium releases to the 200-F and 200-H area seepage basins are shown in Figure III-5. Of the total of 420,000 Ci of tritium sent to the basins through 1975, 100,000 Ci has migrated to Four Mile Creek. The remainder is in transit in the ground water or has decayed (half-life 12.3 yr) or evaporated from the surface of the basins.

Annual releases to the 200-F and 200-H seepage basins excluding tritium are shown in Figure III-6, and the ^{137}Cs and ^{90}Sr releases are shown in Figure III-7. Exceptions to the generally decreasing trends in activity discharges to the 200-F and H seepage basins were in 1960 and 1964 for total activity (primarily ^{95}Zr-Nb, $^{103,106}Ru$, and $^{141,144}Ce$), in 1968 and 1969

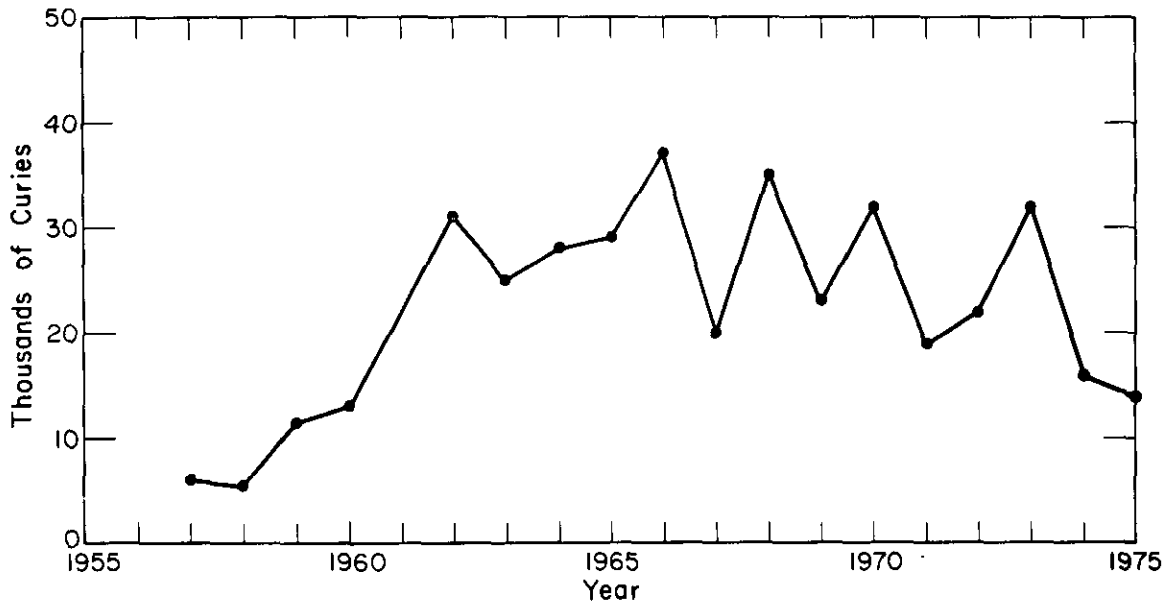

FIGURE III-5. Releases of Tritium to the 200-F and 200-H Seepage Basins at SRP

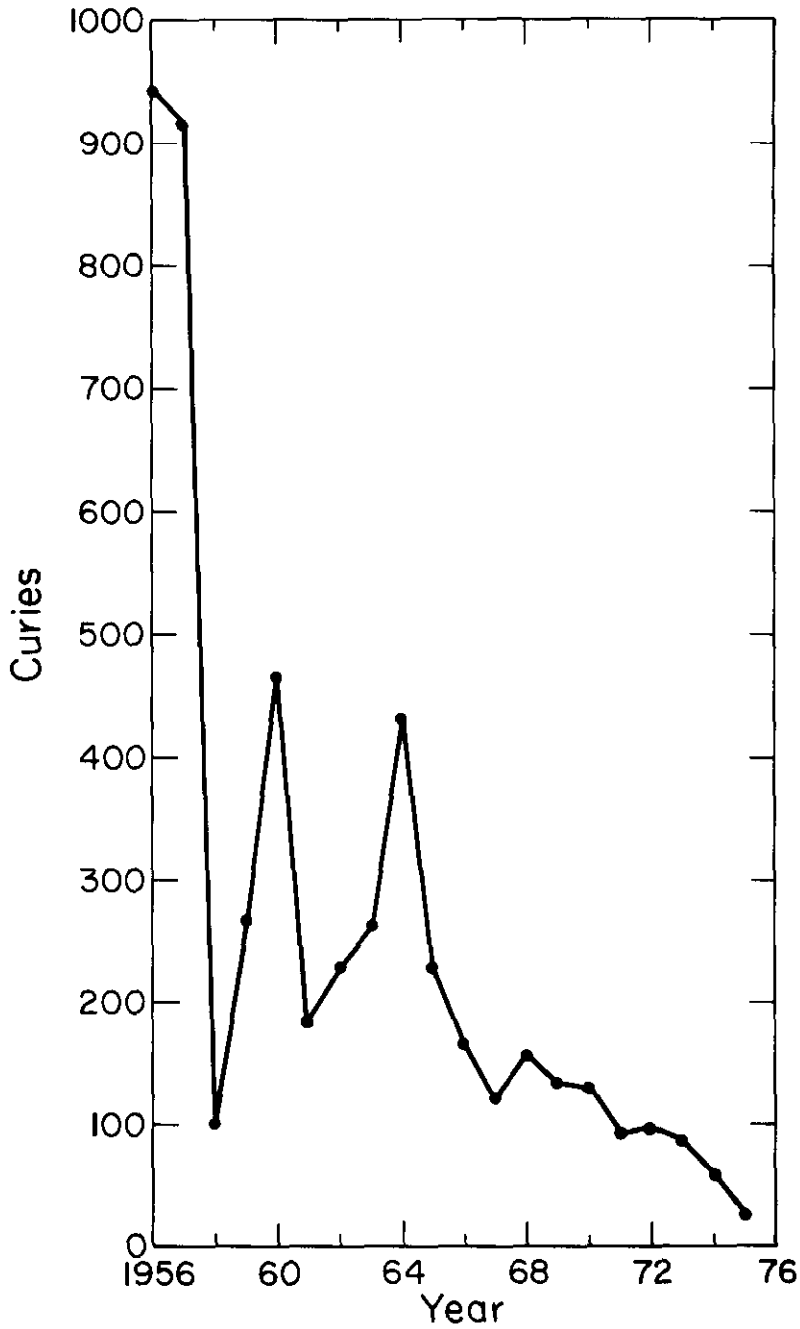

FIGURE III-6. Fission Products and Activation Products (not including tritium) Released to Separations Areas Seepage Basins (200 F & H) at SRP

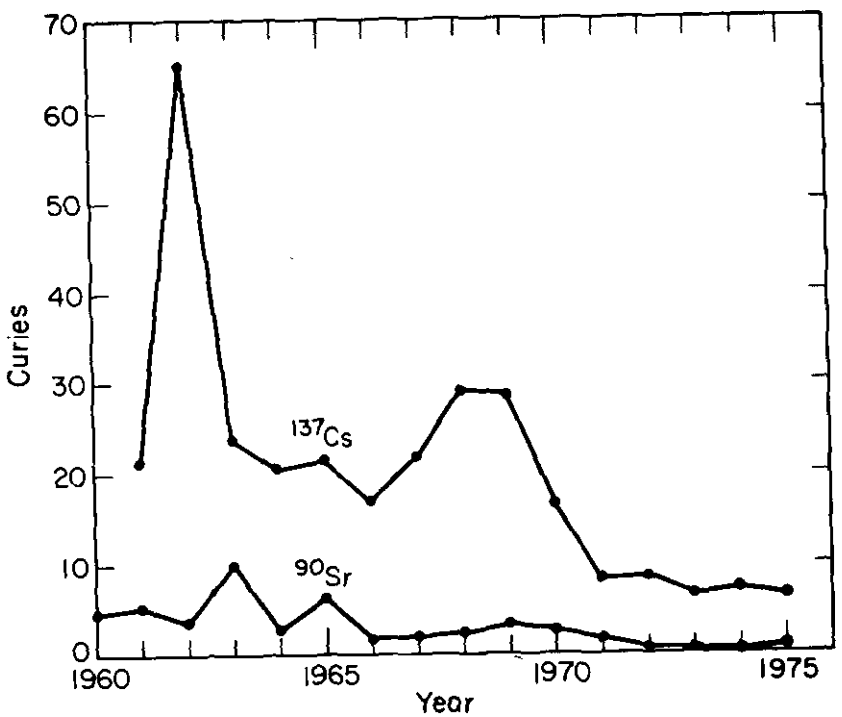

FIGURE III-7. ^{90}Sr and ^{137}Cs Discharged to 200-F and 200-H Seepage Basins at SRP

for ^{137}Cs, and in 1963 for ^{90}Sr. These exceptions were caused by process variations in waste management equipment (acid recovery units, evaporators, cesium removal columns), diversion of contaminated cooling water, small spills, and increases in waste processing volumes. The increase in ^{137}Cs released to seepage basins in 1962 was associated with initial operation of the F-Area evaporator for the evaporation of high-level waste. Later reductions resulted primarily from installation of cesium removal columns to treat the evaporator condensate.

During 1974 and 1975, about 57 and 26 Ci/yr, respectively, of total activity containing about 8 Ci of ^{137}Cs and less than 1 Ci of ^{90}Sr have been discharged to separations areas seepage basins. These decreases have been brought about by improved waste treatment techniques, processes, and monitoring. Descriptions of present techniques are given in Section II, and details of their operation are given in Reference 3.

Routine sampling of the ground water and several cores drilled from the soil at the bottom of a basin show that the cesium is tightly held in the clay. Present indications are that cesium has reached levels of 2×10^{-10} Ci/g of soil at depths of 6 to 18 ft in the 21 years that the seepage basins have been in use. The concentration of ^{137}Cs in the ground water in equilibrium with this soil is below the concentration guide for water given in ERDAM-0524.[2]

Ground water and soil samples show that strontium migrates through the soil more rapidly than cesium. A total of about 9 Ci of ^{90}Sr has migrated to Four Mile Creek from the 200-F and H basins through 1975 from a total of about 76 Ci discharged to the basins. In 1975, the highest measured concentration in Four Mile Creek below these basins was 1.52×10^{-13} Ci/ml, which is below the concentration guide for water given in ERDAM-0524.[2]

In addition to the 200-Area seepage basins, a basin in K Area with a capacity of 50 million gal is currently being used for disposal of the fuel and target storage basin purge water. The purpose of this basin (similar ones exist in 100-P and 100-C areas) is to receive contaminated cooling water in the event of a reactor accident. The 100-K basin first received discharges of fuel storage basin water in 1965, in order to provide a delaying facility to permit decay of unusual amounts of ^{32}P (14-day half-life) activity. The basin has continued in similar service since the ^{32}P problems were alleviated, and functions in much the same way as the 200-F and 200-H seepage basins by providing a mechanism for decay of certain radionuclides and for smoothing out of batchwise releases. Tritium releases to the basin are shown in Figure III-8. Increased tritium releases to this basin in 1972 to 1973 resulted from purges to reduce fuel and target storage basin tritium concentrations (as discussed under releases to streams). Tritium is the only

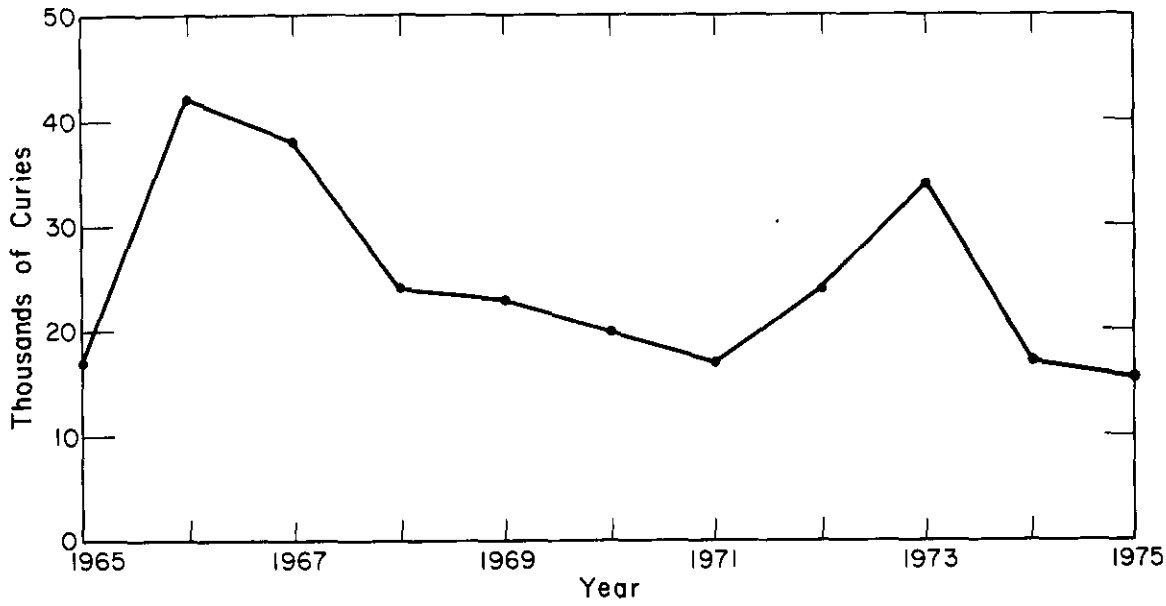

FIGURE III-8. Releases of Tritium to the 100-K 50-million-gallon Basin At SRP

activity observed to date migrating from the basin; a total of 87,000 Ci migrated to Indian Grave Branch from 1969 to 1975. As shown in Table III-1, tritium was the major radioactive constituent released to this basin in 1975; releases of other activities have decreased in recent years as a result of the improved fuel storage basin operation discussed previously for releases to effluent streams.

Annual and total quantities discharged to these and other SRP earthen basins are given in Appendix A and in DP-1349.[3] Included in DP-1349 are data and descriptions for those reactor area seepage basins that are not currently in use. Appendix A also contains an inventory of miscellaneous sites of buried radioactivity, including the back-filled 100-R seepage basins.

RELEASE FROM THE SOLID RADIOACTIVE WASTE STORAGE SITE (BURIAL GROUND)

The burial ground is used to store all solid radioactive waste produced at the Savannah River Plant as well as occasional special ERDA shipments from offsite. Monitoring wells (described in Section II) provide the means for surveillance of the buried waste. The information obtained from monitoring with each of these well systems is as follows:

- Perimeter Wells: In 19 years of monitoring, levels of radioactivity in these wells have been within natural background fluctuations. No migration of radioactivity is indicated by these data.

- Boreholes: Twelve years of monitoring the gamma radiation in these wells indicates that the radioactive wastes remain where emplaced in the trenches.

- Trench Wells: Of the 24 trench wells, 16 are characteristically dry and have not yielded collectable water. Eight wells are wet at least some of the time, and five of the eight are characteristically wet wells from which water is routinely collected. In these five wells, the average water height above the bottom of the trenches is between 4 to 8 ft in two wells, between 2 to 4 ft in two others, and between 0 to 2 ft in the fifth; there has been no observation of overflow from the trenches. The "perched" water in contact with waste always contains beta-gamma radioactivity, at an average of $\sim 10^3$ pCi/l ($\sim$100 times the average natural background for shallow well water).

- Grid Wells: The principal monitoring observation from this system is that tritium has migrated from the waste emplacements. The inventory of tritium in the ground water beneath the 80-acre site is $\sim 5 \times 10^4$ Ci, assuming a 40-ft depth of penetration into the water table. About 5×10^3 Ci of tritium has migrated to the southwest of the burial ground fence beneath a tract of about 16 acres. The total tritium inventory in the ground water is about one-fourth of the amount predicted from the quantity buried and its known mobility. There is no evidence of plutonium migration from buried solid waste.* Migration of beta-gamma nuclides into the ground water from the buried waste is evident at only one location.* This well contains beta-gamma radioactivity at about 15 times the background level. The rate of lateral movement of the nuclides in the ground water is about one-fiftieth of the rate of water movement (less than 1 foot per year). Thus, the radioactivity will decay to background levels within a distance of 100 ft from the well. In the case of tritium migration, the dose-to-man vector through Four Mile Creek to the Savannah River to downstream river water users at Port Wentworth, Georgia, and Beaufort, South Carolina, is very small (<<1 man-rem).

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* There is a low level of plutonium and beta-gamma contamination in the ground water over a 12-acre portion of the burial ground which contains 14 of the grid wells. The source of this contamination is not the solid waste emplacements, but transfer and storage operations with contaminated kerosene-tributyl phosphate solvent before disposal by incineration at the burial ground. Small leaks in two of the solvent storage tanks in 1968 and a transfer accident in 1962, in which 40 gal of contaminated solvent was pumped into a test well, resulted in a film of contaminated solvent containing an estimated 5 mCi of plutonium and an estimated 100 mCi of beta-gamma isotopes across 12 acres of the ground water table.[4] The solvent residue has almost completely dissipated, but residual traces of plutonium and beta-gamma radioactivity from these incidents occur in four of the monitoring wells. This radioactivity complicates the interpretation of monitoring results from this sector. This low-level mixture of radionuclides is sorbed on a thin layer of soil at the water table; its future rate of movement should be in the range of inches per year to less than a foot per year.